CLAIMS

1. An audio signal band extending apparatus comprising:

noise generating means for generating a noise signal level-correlated to and so as to change according to one of a level of an inputted signal and a level of a signal in a partial band obtained by bandpass-filtering the inputted signal using bandpass filtering means;

signal processing means for multiplying a generated noise signal by a predetermined transfer function so that, at a lower limit frequency of a predetermined band-extended signal, a level of the generated noise signal substantially coincides with the level of the inputted signal and a spectral continuity thereof is kept when addition is executed by adding means, and for outputting a signal having a multiplication result; and

adding means for adding up the inputted signal and an outputted signal from said signal processing means, and for outputting a signal having an addition result.

2. The audio signal band extending apparatus as claimed in claim 1, further comprising:

first conversion means provided so as to be inserted at the previous stage of said bandpass filtering means, said first conversion means converting the inputted signal into a digital signal; and

second conversion means provided so as to be inserted between said signal processing means and said adding means, said second conversion means converting the outputted signal from said signal processing means into an analog signal.

3. The audio signal band extending apparatus as claimed in

claim 1, further comprising:

oversampling type low-pass filtering means provided so as to be inserted at the previous stage of said bandpass filtering means and said adding means, said oversampling type low-pass filtering means oversampling and low-pass filtering the inputted signal, and outputting a resultant signal to said bandpass filtering means and said adding means.

4. The audio signal band extending apparatus as claimed in claim 1, further comprising:

oversampling type low-pass filtering means provided to be inserted at the previous stage of said adding means, said oversampling type low-pass filtering means oversampling and low-pass filtering the inputted signal, and outputting a resultant signal to said adding means; and

oversampling means provided to be inserted between said noise generating means and said signal processing means, said oversampling means oversampling the noise signal from said noise generating means, and outputting a resultant signal to said signal processing means.

5. The audio signal band extending apparatus as claimed in any one of claims 1 to 4,

wherein said noise generating means comprises:

level signal generating means for detecting a level of a signal inputted to said noise generating means, and for generating and outputting a level signal having a detected level;

noise signal generating means for generating and outputting a

noise signal according to the signal inputted to said noise generating means; and

multiplying means for multiplying the level signal from said level signal generating means by the noise signal from said noise signal generating means, and for outputting a noise signal having a multiplication result.

6. The audio signal band extending apparatus as claimed in claim 5,

wherein said noise signal generating means comprises a delta sigma modulator type quantizer, generates a quantized noise signal of a signal inputted to said noise signal generating means, and outputs a generated quantized noise signal as the noise signal.

7. The audio signal band extending apparatus as claimed in any one of claims 1 to 4,

wherein said noise generating means comprises:

first cutting-out means for cutting out predetermined higher-order bits from the signal inputted to said noise generating means, and for outputting a signal including the higher-order bits;

at least one second cutting-out means for cutting out at least one of predetermined intermediate-order bits and predetermined lower-order bits from the signal inputted to said noise generating means, and for outputting a signal including the at least one of the predetermined intermediate-order bits and predetermined lower-order bits; and

multiplying means for multiplying a signal from said first cutting-out means by a signal from said second cutting-out means, and for

outputting a noise signal having a multiplication result.

8. The audio signal band extending apparatus as claimed in claim 7,

wherein said second cutting-out means cuts out either one of a combination of intermediate-order bits and lower-order bits, and two intermediate-order bits, at different bit locations and with a predetermined bit width, adding up cut out bits, and outputs a signal having an addition result.

9. The audio signal band extending apparatus as claimed in claim 7,

wherein said second cutting-out means cuts out either one of a combination of intermediate-order bits and two lower-order bits, and three intermediate-order bits, at different bit locations and with a predetermined bit width, adding up cut out bits, and outputs a signal having an addition result.

10. The audio signal band extending apparatus as claimed in claim 7, further comprising:

independent noise generating means for generating a noise signal independent of the inputted signal; and

further adding means for adding up the noise signal from said second cutting-out means and the noise signal from said independent noise generating means, and for outputting a signal having an addition result to said multiplying means.

11. The audio signal band extending apparatus as claimed in claim 10,

wherein said independent noise generating means generates a plurality of noise signals different from each other, adds up said plurality of noise signals, and outputs a signal having an addition result.

12. The audio signal band extending apparatus as claimed in claim 10 or 11,

wherein said independent noise generating means generates a diamond dithering noise signal.

13. The audio signal band extending apparatus as claimed in any one of claims 1 to 4,

wherein said noise generating means comprises:

non-uniformity quantization means for quantizing a signal inputted to said noise generating means non-uniformly relative to a level thereof, and for outputting a resultant signal;

dequantization means for executing a processing opposite to a processing executed by said non-uniformity quantization means on a signal from said non-uniformity quantization means, and for outputting a resultant signal; and

subtraction means for generating and outputting a quantized noise signal of the signal inputted to said noise generating means by calculating a difference between the signal inputted to said noise generating means and a signal from said dequantization means.

14. The audio signal band extending apparatus as claimed in claim 13,

wherein said non-uniformity quantization means quantizes an inputted signal so as to increase a quantization width as a level of the

inputted signal is larger.

15. The audio signal band extending apparatus as claimed in claim 13 or 14,

wherein said non-uniformity quantization means compresses a run length of a linear code of L bits into 1/N thereof so as to generate and output data of M bits, where L, M and N are positive integers each of which equals to or larger than 2.

16. The audio signal band extending apparatus as claimed in any one of claims 13 to 15,

wherein said non-uniformity quantization means converts a linear code of L bits that consists of continuous data Q0 of continuous bits each having a predetermined logic and being allocated in a higher order part, an inverted bit T0 that breaks continuity of the continuous data Q0, and lower-order data D0 following the inverted bit T0, into compressed data of M bits consisting of compressed continuous data Q1 obtained by compressing a run length of the continuous data Q0, an inverted bit T1 for that breaks continuity of the compressed continuous data Q1, compressed residual data F1 representing a residue generated upon compressing the run length, and mantissa data D1 obtained by rounding the lower-order data D0, and outputs the compressed data of M bits, and

wherein, provided that the run length of the continuous data Q0 is L0, a run length of the compressed continuous data Q1 is L1, and that N is an integer equal to or larger than 2, the run length L1 of the compressed continuous data Q1 and the compressed residual data F1

are expressed by L1 = Int (L0/N) and F1 = L0 mod N, respectively, where Int is a function that represents an integer value of an argument, and A mod B is a function that represents a residue obtained when A is divided by B.

17. The audio signal band extending apparatus as claimed in any one of claims 13 to 15,

wherein said dequantization means extends a compressed data that consists of compressed continuous data Q1 of continuous bits each having a predetermined logic and being allocated in a higher-order part, an inverted bit T1 that breaks continuity of the compressed continuous data Q1, compressed residual data F1 representing a residue generated upon compressing a run length of the compressed continuous data Q1, and a mantissa data D1, by extending the run length of the compressed continuous data Q1 by "N" times, adding continuous data having a length corresponding to a value of the F1, adding an inverted bit T0 that breaks continuity of Q0, further adding the mantissa data D1 to a resultant data, reading out the continuous data Q0, the inverted bit T0, and the mantissa data D0, and outputting an extended data, and

wherein, provided that a run length of the continuous data Q0 is L0, a run length of said compressed continuous data Q1 is L1, a residue obtained from the compressed residual data F1 is F1, and N is an integer equal to or larger than 2, the run length L0 and the mantissa data D0 are expressed by L0 = L1*n+F1 and D0 = D1, respectively, where * is an arithmetic symbol representing multiplication.

18. The audio signal band extending apparatus as claimed in any one of claims 13 to 17,

wherein said non-uniformity quantization means floating-encodes an inputted linear code into a floating code having a predetermined effective bit length, and outputs an encoded signal having the floating code.

19. The audio signal band extending apparatus as claimed in any one of claims 1 to 18,

wherein said noise generating means comprises:

table memory means for storing a relationship between the signal inputted to said noise generating means and a noise signal level-correlated to the signal inputted to said noise generating means so as to change according to a level of the signal inputted to said noise generating means; and

conversion means for, responsive to the signal inputted to said noise generating means, reading out and outputting a noise signal corresponding to the signal inputted to said noise generating means from said table memory means.

20. The audio signal band extending apparatus as claimed in any one of claims 1 to 19,

wherein said signal processing means comprises at least first filtering means, and

wherein said signal processing means filters out frequency bands higher than a frequency band of the inputted signal.

21. The audio signal band extending apparatus as claimed in any

one of claims 1 to 20,

wherein said signal processing means comprises at least (1/f) filtering means, and

wherein said signal processing means applies a (1/f) reduction characteristic to a higher frequency band spectrum of the signal inputted to said signal processing means.

22. The audio signal band extending apparatus as claimed in any one of claims 1 to 21,

wherein said signal processing means comprises at least echo adding processing means, and

wherein said signal processing means adds an echo signal to a higher frequency band spectrum of the signal inputted to said signal processing means.

23. The audio signal band extending apparatus as claimed in claims 1 to 22,

wherein said signal processing means comprises at least second filtering means, and

wherein said signal processing means filters out frequency bands higher than a frequency band of the signal inputted to said signal processing means so as to include frequency bands exceeding a Nyquist frequency.

24. An audio signal band extending method including:

a noise generating step of generating a noise signal level-correlated to and so as to change according to one of a level of an inputted signal and a level of a signal in a partial band obtained by

bandpass-filtering the inputted signal using a bandpass filtering step;

a signal processing step of multiplying a generated noise signal by a predetermined transfer function so that, at a lower limit frequency of a predetermined band-extended signal, a level of the generated noise signal substantially coincides with the level of the inputted signal and a spectral continuity thereof is kept when addition is executed in an adding step, and of outputting a signal having a multiplication result; and

an adding step of adding up the inputted signal and an outputted signal from said signal processing step, and of outputting a signal having an addition result.

25. The audio signal band extending method as claimed in claim 24, further including:

a first conversion step inserted and executed prior to said bandpass filtering step, said first conversion step converting the inputted signal into a digital signal; and

a second conversion step inserted and executed between said signal processing step and said adding step, said second conversion step converting the outputted signal from said signal processing step into an analog signal.

26. The audio signal band extending method as claimed in claim 24, further including:

an oversampling type low-pass filtering step inserted and executed prior to said bandpass filtering step and said adding step, said oversampling type low-pass filtering step oversampling and low-pass

filtering the inputted signal, and outputting a resultant signal to said bandpass filtering step and said adding step.

27. The audio signal band extending method as claimed in claim 24, further including:

an oversampling type low-pass filtering step inserted and executed prior to said adding step, said oversampling type low-pass filtering step oversampling and low-pass filtering the inputted signal, and outputting a resultant signal to said adding step; and

an oversampling means step inserted and executed between said noise generating step and said signal processing step, said oversampling means oversampling the noise signal from said noise generating step, and outputting a resultant signal to said signal processing step.

28. The audio signal band extending method as claimed in any one of claims 24 to 27,

wherein said noise generating step includes:

a level signal generating step of detecting a level of a signal inputted to said noise generating step, and of generating and outputting a level signal having a detected level;

a noise signal generating step of generating and outputting a noise signal according to the signal inputted to said noise generating step; and

a multiplying step of multiplying the level signal from said level signal generating step by the noise signal from said noise signal generating step, and of outputting a noise signal having a multiplication

result.

29. The audio signal band extending method as claimed in claim 28,

wherein said noise signal generating step includes a delta sigma modulator type quantizer step, generates a quantized noise signal of a signal inputted to said noise signal generating step, and outputs a generated quantized noise signal as the noise signal.

30. The audio signal band extending method as claimed in any one of claims 24 to 27,

wherein said noise generating step includes:

a first cutting-out step of cutting out predetermined higher-order bits from the signal inputted to said noise generating step, and of outputting a signal including the higher-order bits;

at least one second cutting-out step of cutting out at least one of predetermined intermediate-order bits and predetermined lower-order bits from the signal inputted to said noise generating step, and of outputting a signal including the at least one of the predetermined intermediate-order bits and predetermined lower-order bits; and

a multiplying step of multiplying a signal from said first cutting-out step by a signal from said second cutting-out step, and of outputting a noise signal having a multiplication result.

31. The audio signal band extending method as claimed in claim 30,

wherein said second cutting-out step cuts out either one of a combination of intermediate-order bits and lower-order bits, and two

intermediate-order bits, at different bit locations and with a predetermined bit width, adding up cut out bits, and outputs a signal having an addition result.

32. The audio signal band extending method as claimed in claim 30,

wherein said second cutting-out step cuts out either one of a combination of intermediate-order bits and two lower-order bits, and three intermediate-order bits, at different bit locations and with a predetermined bit width, adding up cut out bits, and outputs a signal having an addition result.

33. The audio signal band extending method as claimed in claim 30, further including:

an independent noise generating step of generating a noise signal independent of the inputted signal; and

a further adding step of adding up the noise signal from said second cutting-out step and the noise signal from said independent noise generating step, and of outputting a signal having an addition result to said multiplying step.

34. The audio signal band extending method as claimed in claim 33,

wherein said independent noise generating step generates a plurality of noise signals different from each other, adds up said plurality of noise signals, and outputs a signal having an addition result.

35. The audio signal band extending method as claimed in claim 33 or 34,

wherein said independent noise generating step generates a diamond dithering noise signal.

36. The audio signal band extending method as claimed in any one of claims 24 to 27,

wherein said noise generating step includes:

a non-uniformity quantization step of quantizing a signal inputted to said noise generating step non-uniformly relative to a level thereof, and of outputting a resultant signal;

a dequantization step of executing a processing opposite to a processing executed by said non-uniformity quantization step on a signal from said non-uniformity quantization step, and of outputting a resultant signal; and

a subtraction step of generating and outputting a quantized noise signal of the signal inputted to said noise generating step by calculating a difference between the signal inputted to said noise generating step and a signal from said dequantization step.

37. The audio signal band extending method as claimed in claim 36,

wherein said non-uniformity quantization step quantizes an inputted signal so as to increase a quantization width as a level of the inputted signal is larger.

38. The audio signal band extending method as claimed in claim 36 or 37,

wherein said non-uniformity quantization step compresses a run length of a linear code of L bits into 1/N thereof so as to generate and

output data of M bits, where L, M and N are positive integers each of which equals to or larger than 2.

39. The audio signal band extending method as claimed in any one of claims 36 to 38,

wherein said non-uniformity quantization step converts a linear code of L bits that consists of continuous data Q0 of continuous bits each having a predetermined logic and being allocated in a higher order part, an inverted bit T0 that breaks continuity of the continuous data Q0, and lower-order data D0 following the inverted bit T0, into compressed data of M bits consisting of compressed continuous data Q1 obtained by compressing a run length of the continuous data Q0, an inverted bit T1 for that breaks continuity of the compressed continuous data Q1, compressed residual data F1 representing a residue generated upon compressing the run length, and mantissa data D1 obtained by rounding the lower-order data D0, and outputs the compressed data of M bits, and

wherein, provided that the run length of the continuous data Q0 is L0, a run length of the compressed continuous data Q1 is L1, and that N is an integer equal to or larger than 2, the run length L1 of the compressed continuous data Q1 and the compressed residual data F1 are expressed by L1 = Int (L0/N) and F1 = L0 mod N, respectively, where Int is a function that represents an integer value of an argument, and A mod B is a function that represents a residue obtained when A is divided by B.

40. The audio signal band extending method as claimed in any

one of claims 36 to 38,

wherein said dequantization step extends a compressed data that consists of compressed continuous data Q1 of continuous bits each having a predetermined logic and being allocated in a higher-order part, an inverted bit T1 that breaks continuity of the compressed continuous data Q1, compressed residual data F1 representing a residue generated upon compressing a run length of the compressed continuous data Q1, and a mantissa data D1, by extending the run length of the compressed continuous data Q1 by "N" times, adding continuous data having a length corresponding to a value of the F1, adding an inverted bit T0 that breaks continuity of Q0, further adding the mantissa data D1 to a resultant data, reading out the continuous data Q0, the inverted bit T0, and the mantissa data D0, and outputting an extended data, and

wherein, provided that a run length of the continuous data Q0 is L0, a run length of said compressed continuous data Q1 is L1, a residue obtained from the compressed residual data F1 is F1, and N is an integer equal to or larger than 2, the run length L0 and the mantissa data D0 are expressed by L0 = L1*n+F1 and D0 = D1, respectively, where * is an arithmetic symbol representing multiplication.

41. The audio signal band extending method as claimed in any one of claims 36 to 41,

wherein said non-uniformity quantization step floating-encodes an inputted linear code into a floating code having a predetermined effective bit length, and outputs an encoded signal having the floating code.

42. The audio signal band extending method as claimed in any one of claims 24 to 41,

wherein said noise generating step includes:

a table memory step of storing a relationship between the signal inputted to said noise generating step and a noise signal level-correlated to the signal inputted to said noise generating step so as to change according to a level of the signal inputted to said noise generating step; and

a conversion step of, responsive to the signal inputted to said noise generating step, reading out and outputting a noise signal corresponding to the signal inputted to said noise generating step from said table memory step.

43. The audio signal band extending method as claimed in any one of claims 24 to 42,

wherein said signal processing step includes at least a first filter step, and

wherein said signal processing step filters out frequency bands higher than a frequency band of the inputted signal.

44. The audio signal band extending method as claimed in any one of claims 24 to 43,

wherein said signal processing step includes at least a (1/f) filtering step, and

wherein said signal processing step applies a (1/f) reduction characteristic to a higher frequency band spectrum of the signal inputted to said signal processing step.

45. The audio signal band extending method as claimed in any one of claims 24 to 44,

wherein said signal processing step includes at least an echo adding processing step, and

wherein said signal processing step adds an echo signal to a higher frequency band spectrum of the signal inputted to said signal processing step.

46. The audio signal band extending method as claimed in claims 24 to 45,

wherein said signal processing step includes at least a second filtering step, and

wherein said signal processing step filters out frequency bands higher than a frequency band of the signal inputted to said signal processing step so as to include frequency bands exceeding a Nyquist frequency.

47. An optical disk system comprising:

a reproduction apparatus for reproducing an audio signal stored in an optical disk; and

the audio signal band extending apparatus as claimed in any one of claims 1 to 23 for extending a band of a reproduced audio signal, and for outputting a band-extended audio signal.

48. A program that includes the respective steps of the audio signal band extension method as claimed in any one of claims 24 to 46.

49. A computer readable recording medium that stores a program including the respective steps of the audio signal band

extension method as claimed in any one of claims 24 to 46.